ARAVAIPA CANYON WILDERNESS AREA

FEDERAL RESERVED WATER RIGHT CLAIMS

In re Aravaipa Canyon Wilderness Area (W1-11-3342), in the General Adjudication of All Rights to Use Water in the Gila River System and Source, Ariz. Sup. Ct., Case Nos. W1-W4.

EXPERT OPINION REPORT

For

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Executive Summary

SWCA Environmental Consultants (SWCA) has been retained by the law firm of Fennemore Craig to provide an expert biological opinion in the adjudication of water rights, in the case of In re Aravaipa Canyon Wilderness Area (W1-11-3342), in the General Adjudication of All Rights to Use Water in the Gila River System and Source, Ariz. Sup. Ct., Case Nos. W1–W4. Specifically, SWCA has been commissioned to review the best available scientific data relevant to the United States' federal reserved water rights claim that the minimal water need of Aravaipa Canyon Wilderness Area is all of the water flowing naturally within the Aravaipa Creek. In addition to the review of existing data, SWCA also reviewed four expert reports (hydrology, fisheries, riparian habitat and recreation) contracted by the Department of Justice (DOJ). These expert reports were submitted to the Special Master in support of the United States' contention that all of the water (base flows and un-impounded flood flows) is required to provide for "the preservation and protection of this relatively undisturbed but fragile complex of desert, riparian and aquatic ecosystems and the native plant, fish and wildlife communities dependent on it" (Public Law 98-406).

The primary intent of this expert report is to review existing data and expert reports on ecosystem processes within the wilderness area and opine on whether or not SWCA believes that all of the water flowing naturally, including all extremes of the annual hydrograph are necessary to fulfill the original purpose of the wilderness area.

The SWCA expert opinion demonstrates that ample scientific evidence exists that there is sufficient surplus in the annual hydrograph to allow for targeted water extraction primarily on the descending hydrograph of destructive flood flows, but also, on prescribed occasions, on the ascending hydrograph of high flows during winter and summer floods. This limited and controlled water extraction will not preclude protection of the annual patterns of the "natural hydrograph" and the ecosystem that is nurtured by the surface and subsurface waters of Aravaipa Creek. Limited patterns of flood water extraction will also have negligible impact on the recreational aspects of the wilderness area. The extreme annual fluctuations in Aravaipa Creek describe a natural pattern of flow from one year to the next, or indeed within a single year, and these flow patterns are clearly associated with flows that are not retained within the wilderness system. SWCA demonstrates that the natural pattern of flow can be maintained while simultaneously extracting some of that flood flow. To that end, SWCA has developed a water extraction model (Opportune Extraction Model, [OEM]) that allows for the extraction of water that is surplus to, and which normally passes through the wilderness system, yet still leaves enough water to meet biological, hydrological, and physical processes for protection of the wilderness area, and does not negatively impact the recreational experience of thousands of annual visitors. Based on the OEM, SWCA analyzed the amount of potential water that could have been extracted from Aravaipa Creek for two time periods, the 52 years from 1932 to 1983 (Wilderness established in 1984) and the 81 years from 1932 to 2012.

All four of the expert reports submitted by DOJ conclude that the only means of protecting wilderness area resources is to meet the government claims for all of the water. However, SWCA believes that each of the experts simply errs on the side of caution and decrees that all of the water is essential, in lieu of empirically demonstrating how much water is necessary for any specific ecosystem or wilderness function. DOJ's experts all also rely on value judgments and not scientific facts to come to their conclusions on wilderness water needs.

With the development of the OEM, however, SWCA has made the effort to empirically demonstrate how much of the un-impounded flood flows are *not* necessary to the protection of the natural hydrograph and therefore available for other beneficial uses. The OEM scenarios that provide the most conservative approach to maintaining existing patterns of the natural hydrograph allow extraction of flood flows up to 500 cfs at a period of time when, the destructive floods of 1,000 cfs, or greater occur. The extraction process is controlled such that minimum and base flows would never be extracted. The OEM indicates that long-term extraction over the 52 years of data recorded (1 January 1932 to 31 December 1983) would have resulted in the capture of 65,105 acre-feet (af) or an annual average of 1,252 af. For the entire period of record from 1932 to 2012 the amount of flow the model would have allowed to be captured would have been 119,658 af, or an annual average of 1,459 af. For the 52 year period analyzed up to the establishment of the wilderness area the model indicates that almost 10 percent (9.6 percent) of the un-impounded flood flow of 15,156 af identified in the federal reserved water rights claim could have been extracted without causing a significant change in the natural hydrograph.

It is important to note that SWCA is not alone in determining that not all of a stream system's natural hydrograph is essential to the management of aquatic and riparian habitats. The U.S. Fish and Wildlife Service has determined that as long as a modified or regulated stream allows for adequate river functions, endangered fish species like those found in Aravaipa Creek will be provided the primary constituent elements necessary for their recruitment. In addition, in a multi-year study on the San Pedro River, a team of scientists determined that only 60 percent of the storm flows were necessary for the maintenance of the riparian ecosystem, not 100 percent as requested in the federal reserved water rights claim for Aravaipa Creek.

Introduction

SWCA Environmental Consultants (SWCA) has been retained by the law firm of Fennemore Craig to provide an expert biological opinion in the adjudication of water rights, in the case of *In re Aravaipa Canyon Wilderness Area* (W1-11-3342), in the *General Adjudication of All Rights to Use Water in the Gila River System and Source,* Ariz. Sup. Ct., Case Nos. W1–W4. Specifically, SWCA has been asked to review available data on ecosystem processes within the Aravaipa Canyon Wilderness Area, including water needs for fisheries, terrestrial wildlife and riparian habitat. To that end, SWCA has been commissioned to review the best available scientific data relevant to the United States' federal reserved water rights claim that the minimal need of Aravaipa Canyon Wilderness Area is *all* of the unappropriated water constituting the natural flow in the area as of August 28, 1984.[4]

Relevant guidance directing the scope of the SWCA effort is found in the findings of the Special Master assigned to resolve the Contested Case, specifically:

> *This case presents the interaction of a federal reserved water right and a vested state law based water right. The United States holds Certificate of Water right No. 87114.0000 for the use of the water flowing in Aravaipa Creek, inside the Aravaipa Canyon Wilderness Area, for recreation and wildlife, including fish, with a priority date of June 1, 1981 (before the wilderness area was designated*).[[5]] *In order to resolve this issue, the scope of that interaction must be considered.*
>
> *The Special Master cannot determine whether the Congress intended to reserve all the unappropriated water flowing naturally within the Aravaipa Canyon Wilderness Area. This question will be answered after applying the guidance of Cappaert, New Mexico, Gila V, and other relevant law to an evidentiary record."* (p. 18, Section IX, ACWA/Nov. 2, 2011)

[4] A significant issue relative to the federal reserved water rights claim that has not been revealed to us is the actual point of compliance for the water right. Is it at the east end of the wilderness boundary, the west end of the boundary, or the USGS gage from which the flow data has been gathered? United States has not clarified this important issue.

[5] A copy of the certificate of water right is provided in Freeport-McMoRan Exh. J

In *Cappaert* the Supreme Court held that "[t]he implied-reservation-of-water-rights doctrine….reserves only that amount of water necessary to fulfill the purpose of the reservation, no more."[6] Following that decision, 2 years later, Chief Justice Rehnquist again stated that "the Court has repeatedly emphasized that Congress reserved '*only that amount of water necessary to fulfill the purpose of the reservation, no more* [our emphasis]'."[7]

The Wilderness Act, the enabling legislation that established the Aravaipa Canyon Wilderness, defined the purpose of the "reservation" as "…a primitive place of great natural beauty that, due to the rare presence of a perennial stream, supports an extraordinary abundance and diversity of native plant, fish, and wildlife, making it a resource of national significance…" and further pointed out that the wilderness area was established for "…the preservation and protection of this relatively undisturbed but fragile complex of desert, riparian and aquatic ecosystems and the native plant, fish and wildlife communities dependent on it…." (Public Law 98-406).

Thus, the primary intent of the SWCA expert report is to review the existing data on ecosystem processes within the Aravaipa Canyon Wilderness Area and opine on whether or not we believe that *all* of the water flowing naturally, including all extremes of the annual hydrograph, is required to provide for "the preservation and protection of this relatively undisturbed but fragile complex of desert, riparian and aquatic ecosystems and the native plant, fish and wildlife communities dependent on it" (Public Law 98-406). In addition to the review of the existing data, SWCA also reviewed four expert reports submitted to the Special Master in support of the United States' claim. These reports include:

1. Swanson, S. 2013. Aravaipa Creek Arizona Federal Reserve Water Rights Claim. U.S. Bureau of Land Management.
2. Bonar, S.A., and N. Mercado-Silva. (no date). In re Aravaipa Canyon Wilderness Area (W1-11-3342), In the General Adjudication of All Rights to Use Water in the Gila River System and Source, Arizona. Sup. Ct., Case Nos. W1-W4. Aravaipa Canyon Wilderness Area Federal Reserved Water Rights Claim: Protection of Fish Resources.
3. Lowclouds Hydrology Inc. (Lowclouds). 2013. Aravaipa Canyon riparian assessment in support of Federal Reserved Water Rights.
4. Moore, S.D. 2013. Aravaipa Canyon Wilderness: Dependence of recreational values on streamflows.

Background

Aravaipa Creek is located along the border of Pinal and Graham counties west of Safford, Arizona. The Aravaipa Canyon basin drains approximately 541 square miles with elevations on the basin's valley floor ranging from 4,300 feet above sea level at its southeastern terminus, to 3,100 feet at the east entrance to Aravaipa Canyon. Aravaipa Creek flows through Aravaipa Valley southeast to northwest and terminates in the San Pedro River (see JE Fuller Hydrology and Geomorphology, Inc. [JE Fuller] et al. 2000 for graphics and more details on physiographic description). The U.S. Bureau of Land Management (BLM) and The Nature Conservancy (TNC) manage the stream and uplands adjacent to the canyon. Much of the property above the canyon is private property. Aravaipa Canyon's 22-mile-long lower portion, beginning

[6] 426 U.S. at 141
[7] New Mexico, 438 U.S. at 700 (citing Cappaert, 426 U.S. at 141); see Arizona v. California, 373 U.S. 546, 6000-01 (1963)

in the canyon-bound reach is perennial with flow supported by various springs. The upper reaches are intermittent and ephemeral.

The flows of Aravaipa Creek are supported by local springs fed by groundwater, as well as surface runoff from its drainage area. The average mean daily discharge reported for a 43-year period (from 1931 to December 1942, and from 1966 to 1998) at a U.S. Geological Survey (USGS) gage on Aravaipa Creek (approximately 6 miles below the west border of the Wilderness) is 34.7 cubic feet per second (cfs). This level of flow provides for an average annual volume of 26,590 acre-feet per year (af/yr). Base flow (measured as minimum daily flow for each month) can vary dramatically from year to year, and can range from 3,200 af/yr (1977) to 27,500 af/yr (1993) (JE Fuller et al. 2000). Data on Aravaipa flows are recorded at USGS and BLM gaging stations located at the east and west ends of Aravaipa Creek (see Plateau Resources 2013). JE Fuller et al. (2000) compared the differences in the flow data gathered at these gages and found the differences to be generally comparable (JE Fuller et al. 2000; Plateau Resources 2013). All four of the DOJ expert reports cited above provide additional introductory details on local geography and general hydrology of the area; further details will not be repeated here.

Riparian Ecology and the "Natural Hydrograph"

Within the scientific community it has been generally undisputed for decades that the characteristics of riparian, or streamside, vegetation communities are especially unique in wildlife productivity within desert areas (see Hubbard 1971; Carothers et al. 1974, 1977; Johnson and Jones 1977). What is also well known is that a significant change in the long-term pattern of annual flow or the basic characteristics of a stream's natural hydrograph can reduce the vigor and productivity of riparian ecosystems(Annear et al. 2004; Merritt and Poff 2010; Poff and Zimmerman 2010).

It is important here to define what is meant by the term "natural hydrograph" and identify the elements of that condition that are currently recognized by the scientific community as necessary to protect and nurture aquatic and terrestrial ecosystems. The relatively uninterrupted annual pattern of flow, i.e., the "natural hydrograph" in Aravaipa Creek consists of seasonally variable flows that contain both base flows (relatively stable flows that are not influenced by floods) and flood flows from winter storm events and summer monsoon rains (see JE Fuller et al. 2000). The annual pattern, and the multi-year variability, in these flows set the stage for the aquatic and terrestrial biological resources that can survive and evolve in the system. Each stream, unless it is dam-regulated or otherwise significantly altered by anthropomorphic influences, or natural causes like earthquakes (e.g., the San Pedro River), etc., has a pattern of flow that is generally dictated by climate, topography, geology, depth to groundwater and other factors (Annear et al. 2004).

A fundamental understanding of what is needed to maintain aquatic and terrestrial stream ecosystems includes four elements of stream flow: longitudinal flows (flows that extend over the length of a stream course); lateral flows (flows that cover the width of the channel); vertical flows (flows that provide sufficient stream depth); and flow duration (the amount of time a flow is at a particular level) (see Annear et al. 2004). The relatively large watershed of Aravaipa Creek can produce large flooding events that scour and reshape floodplain habitats. Moderate to high floods reshape the riparian habitats by scouring and depositing sediments onto substrates above the active stream channel and redistribute organic material that can benefit healthy riparian vegetation (Annear et al. 2004; Carothers and Brown 1991; Smith et al. 1991; Poff et al. 1997; Shafroth et al. 2000, 2002; Bunn and Arthington 2002; Leenhouts et al. 2006). These same flows also can benefit aquatic habitats by redistributing gravel and fine substrates that are important for fish spawning and rearing habitats. Extreme flooding events can be destructive to the ecosystem as well. Large floods uproot riparian vegetation and scour instream aquatic food base resources that fishes rely on (Meffe and Minckley 1987). In addition, floods of large magnitudes are important events that can be detrimental to non-native fish assemblages that are known to impair the native fish community (Meffe and Minckley 1987). Studies have shown that large floods preferentially impair non-native fishes over flood adapted natives (Gido et al. 2013; Propst et al. 2008; Minckley and Meffe 1987). This "re-setting" of the fish community can give the native fishes at least a temporary window in time to rebound from the negative (competitive and predatory) interactions with non-natives.

The remarkable variability of flows occurring in Aravaipa Creek is exemplified by the largest recorded flood, which occurred in 1983—this single flood had estimated peak instantaneous discharges of 30,000 cfs (see Plateau Resources 2013) in a stream that regularly flows 6–18 cfs during most summer months; winter and summer floods in excess of 10,000 cfs recur at approximate 10-year intervals (JE Fuller et al. 2000). This natural variability in flood flow (especially the larger flood events) includes a large amount of water that *is not retained within the system, but simply passes through.* Base flows, or the non-flood influenced flows (primarily sourced from groundwater discharge at springs and seeps) also express a high degree of variability. For example; the lowest flows (6–10 cfs) have been recorded in May and June, with the highest flows (16–18 cfs) recorded during January, February, and March (see JE Fuller et al. 2000; Plateau Resources 2013; Swanson 2013).

It is clear that the summer and winter floods occur with some regularity and they can be destructive to the riparian habitats (Swanson 2012; JE Fuller et al. 2000). The most recent destructive flood occurred in late summer of 2006. The instantaneous discharge during the 2006 flood was 28,000 (Plateau Resources 2013). The level of disturbance to the riparian habitat is evidenced by quoting Ranger Patrick O'Neill assessing the damage to 11 miles of stream terraces within the wilderness area after a couple of days of rain in late July:

> *It doesn't look at all like it did. Most of the riparian vegetation is gone, especially in the western half. Where the cottonwoods and willow are the dominant trees, that's* [sic] *pretty much gone everywhere*. (Beal 2006)

The point that is self-evident is that there is tremendous variability in stream flow levels within a year, within a season and between years and between periods of years. The variability in Aravaipa Creek flows controls the aquatic and riparian habitats that support the ecosystem. The ecosystem that is supported by the variability in flow has adapted through time to both very dry years and very wet years.

The extreme annual fluctuations in Aravaipa Creek describe a natural pattern of flow from one year to the next, or indeed within a single year, and these flow patterns are clearly associated with flows that are not retained within the wilderness system. We demonstrate below that the natural pattern of flow can be maintained while harvesting some of that flood flow. However, first it is important to review the details of each of the expert's reports.

Expert Reports

Each of the four DOJ reports (Bonar and Mercado-Silva [no date], Lowclouds [2013], Moore [2013] and Swanson [2013]) includes background information in their respective fields of expertise, including fisheries, riparian habitats, recreation and hydrology. Each of the expert reports focuses on the need to maintain a "natural hydrograph" within Aravaipa Creek, and they are consistent in providing summary statements indicating that to protect the wilderness area it is essential to protect the critical elements of the natural hydrograph. Generally, these critical elements include an appropriate flow regime, and variations in that flow regimen including water velocities, depths, microhabitats and temperatures, that nurture ecosystem components; they also include water relatively free of pollutants and non-native predators and competitors. And, as stated before, in these desert streams the variation in flow can change from one year to the next by an order or two of magnitude. Surprisingly, none of the experts recognizes or admits that a portion of many of the flood flows consist of water that is surplus to the system needs, and each of them believes that all the water must be granted to the United States in the federal reserved water right. SWCA believes that each expert simply errs on the side of caution and decrees that all of the water is essential, rather than attempting to empirically demonstrate how much water is necessary for any specific ecosystem or wilderness function. Interestingly, even the federal government at one time believed that only a portion of the flood flows in the San Pedro River, to which Aravaipa Creek is a tributary, were essential to the maintenance of the riverine ecosystem (see Jackson 1987). In a multi-year study on the assessment of water conditions and management opportunities in support of riparian values, a team of scientists concluded that recommendations for instream flows only included 60 percent of natural storm flows (Jackson et al 1987). Then, apparently ignoring the scientific recommendations, the BLM (2006) later went on to make a federal reserved water rights claim on the San Pedro River for *all* of the water.

SWCA agrees that protection of the critical elements of the natural hydrograph is essential; however, we follow the logic of the science produced by previous studies on the San Pedro River (Jackson et al. 1987) and we strongly disagree that to do this *all* the water must remain in Aravaipa Creek.

With the exception of the expert report on recreation (Moore 2013), the basis for the experts' conclusions rests on their assumptions that any alteration of the "natural hydrograph" of Aravaipa Canyon would result in loss of stream integrity through some significant level of change in natural variation within the flow regime. What each of the experts accurately maintains is that changes in base flow, or scouring peak flows, or water temperature, or sediment concentrations or periodicity of flow have the potential to cause changes to the ecosystem. Interestingly, all of the experts appear to admit that the best available science supports the fact that minor alterations in the hydrograph could take place without compromising critical elements. However, each of the three natural resource experts (hydrology, riparian and fisheries) depart from scientific assessments and make statements apparently based on value judgments when it comes to summarizing whether or not the ecosystem needs *all* the natural flow.

For example, Swanson (2013), addressing system hydrology, presents his scientific concerns and then summarizes with value judgments in the following statements: "*Thus, the natural flow regime not only creates a mosaic of available habitats, but also influences the distribution of plants and animals throughout those habitats (Richter et al. 1997)*" (p. 3). Swanson continues, "*The water right must address seasonal variability in base flows and high flows, preferably recommending monthly flows to address variability of base flows and <u>preserving as much of the natural flood regime as possible (King et al. 2003)</u>* [our emphasis] (pp. 3–4). Finally, Swanson reveals his conclusion, mixing hydrological terms with a personal value judgment in the following: "…*approximately sixty-six percent of the water passing through the canyon is associated with random flood events that are critical to maintaining the <u>wilderness character</u> of the ecosystem*" [our emphasis] (p. 5).

Swanson's summary response to the request for clarification from the Special Master to quantify the hydrological needs of the wilderness area is presented as follows: "*Based on the range of flood flows in the table above and the stochastic nature of these events, identifying a specific quantified flood regime (e.g. magnitude, duration, frequency) suitable for maintaining the wilderness ecosystem is not practical for the water right claim. As a surrogate for a specified flood regime, a mean annual volume of 24,600 ac-ft is claimed to protect the annual wilderness character of the hydrograph*" (p. 6).

We agree that Swanson's perception of maintaining seasonal variability and "*preserving as much as the flood regime as possible*" are truly important, but he simply has not made the case from a hydrological perspective that maintenance of the wilderness ecosystem needs *all* of the water. In addition, as we stated before, the point from which Swanson's data are obtained is a gaging station located several miles below the western boundary of the wilderness. Swanson admits that over half (15,156 af) of the water gauged

(24,600 af) is flood flow that has not been retained within the system, is not recharging the apparently full water table, and has not benefited the aquatic resources other than providing some scouring of the channel.

Addressing their understanding of the native fish needs, Bonar and Mercado-Silva (no date), after making similar statements on maintaining natural variability in flow, make the following sweeping conclusion: "*Any human derived departure from natural physical, chemical, and biological conditions in an aquatic ecosystem will have short and long term consequences to its native biota*" (p. 10).

This statement that "any human derived departure from natural….etc." is a "departure" from what was intended to be a scientific review of the needs of fishes in Aravaipa Canyon. Bonar and Mercado-Silva's statement is a value judgment and one not based upon scientific fact. They make no attempt to indicate why "*any*" derived departure from the natural physical, chemical, and biological conditions in an aquatic ecosystem (no matter of what magnitude or of what nature human) will have short- and long–term consequences to the native biota; they simply make the unsupported statement. In their abstract, these authors summarize, "*We conclude that the long term viability of valuable native Aravaipa Creek fishes requires that the natural hydrograph is maintained unaltered*" (p. 3). Again, there is not scientific, peer reviewed support for the statement. However, in the introductory text of their report, they vacillate, if not contradict the "*unaltered*" term and clarify what they may really mean by stating…."*To sustain a natural desert fish community, such as that exists in Aravaipa Creek, maintenance of the natural hydrograph, <u>to the extent possible</u>, is critical*" [our emphasis] (p. 4). These authors seem to stress that the natural hydrograph is what has ensured the long-term viability of Aravaipa Creek fishes, ignoring management actions such as the fish barrier, limited and controlled entry and closure of the area to fishing that are assumed by the U.S. Fish and Wildlife Service (USFWS) as positive management actions (USFWS 2012). After apparently forgetting that they previously qualified the need for an "unaltered" hydrograph to maintain the variability of flows "*to the extent possible'*, deeper in their text they state*…."Any departure from these natural conditions will impose changes to the biotic community that exist in the ecosystem*" (p. 7). In summary, the Bonar and Mercado-Silva report, while containing much valuable and accurate information on the fishery of the area is rife with value judgments more typical of a preservationist's plea than a peer reviewed scientific document.

The expert report (authors unknown) hereafter referred to as "Lowclouds Hydrology Inc." or "Lowclouds" reviews and describes the water needed to support the riparian ecology in Aravaipa Canyon, Arizona. Lowclouds (2013) begins by describing the seasonality of the "*wild flow regime*" that characterizes Aravaipa Creek and provides substantial detail on the annual consumptive water use regarding seasonal rates of evapotranspiration of the streamside vegetation. The authors demonstrate that changes in the "natural" base flow can be accounted for primarily as a function of spring and summer leaf-out of streamside plants. They discuss how the variable flow regimen results from the interplay of three hydrological processes—groundwater discharge, evapotranspiration and seasonal flooding—that combine to create the annual hydrograph, and they accurately conclude that:

> *Any water right to protect the aquatic and riparian ecosystem of Aravaipa Canyon Wilderness must mimic this pattern of streamflow to protect the integrity of these remarkable ecosystems.* (p. 3)

Another important element of the natural hydrograph Lowclouds (2013) emphasizes that is critical to the riparian vegetation involves the role of seasonal flooding in the successful recruitment of herbaceous and woody vegetation. They observe:

> *Following germination of freshly deposited seeds in early spring, survival of the seedlings is only probable if the roots of the new seedlings can keep pace with the*

> *declining water table as flows recede through the remainder of the growing season. Thus establishment of new cohorts of these pioneer species tends to occur with wet winters and springs, and a long, slow, natural recession from high-season flows to base flows (Stromberg 2001, Stromberg et al 2007). From this example, it is clear that every component of the natural hydrograph impacts the community structure of the riparian ecosystem.* (p. 7)

SWCA disagrees with Lowclouds on the characterization of Aravaipa Canyon having "long, slow, natural recession from high-season flows to base flows". In Aravaipa Canyon, the high flows after winter and summer floods normally return to base flows very quickly after the storm events (see Plateau Resources 2013). The papers cited by Lowclouds, Stromberg 2001 and Stromberg et al. 2007, to support the contention that floods recede slowly, are not describing canyon-bound systems like Aravaipa Canyon. In fact, neither of the Stromberg documents has any reference to Aravaipa Canyon or Creek at all. On the subject of "how much water is enough" to provide for the needs of the riparian habitat, Lowclouds (2013) opines:

> *….the occurrence of flood flows is random within the two storm seasons, with some years producing more water in winter and other years producing higher flows in the summer. The stochastic nature of these storm events makes it impractical to specify a flood regime (other than the natural flood regime) for the wilderness;' however, the importance of these seasonal floods to the ecology of the canyon cannot be overemphasized.* (p. 4)

"Impractical" to specify a flood regime for the wilderness? Is the author, Lowclouds, really saying that since it will be too much effort to investigate the Aravaipa Canyon Wilderness' needs more thoroughly, that it needs all the water by default? As with the opinions of Swanson and Bonar and Mercado-Silva we agree with the author's insistence that the *patterns* of the natural hydrograph be maintained, but we disagree with the contention that *all* of the water must be reserved to provide those elements critical to the riparian ecosystem. The riparian habitats and their recruitment depend upon flood flows for seedling establishment and growth, and given the random nature of these flood flows from one year to the next, and from one decade to the next, these flow patterns are known to vary by at least two orders of magnitude through a long-term hydrologic cycle (e.g., one order of magnitude from a medium flow of 300 cfs is 3,000 cfs, two orders of magnitude would be 30,000 cfs).

Moore (2013) presents an expert report on how recreational values depend upon stream flows in Aravaipa Canyon Wilderness. Moore generally supports the fact that the Aravaipa Canyon recreational experience is directly related to the presence of water, but does not provide any evidence that the adjudication of a federal reserved water right is important to those experiences. Interestingly, in an 18-page questionnaire mailed to approximately 800 Wilderness Area visitors (83 percent response rate) he and his associates (Moore et al. 1990) found the following:

> *…the direct recreational benefit of Aravaipa Creek would be nearly zero if streamflows were nonexistent. Direct benefits would increase with increasing stream\flows until 23 CFS is reached. Beyond that flow, visitors would perceive less direct recreational benefit*.

In other words, the pattern of the natural hydrograph, with low flows (anything below 23 cfs) and flood flows (anything above 23 cfs) are not particularly appreciated by visitors. Thus, other than documenting visitor use levels in the wilderness area the expert report on recreational values has no real bearing on the question of whether or not human use data provide anything relevant to the federal reserved water rights issue.

Existing Disturbances to Stream Flow and Natural Hydrograph

With the exception of the expert report focused on the recreation use of the area, the other three reports leave the reader with the impression that the wilderness area and surrounding land is generally pristine with a pattern of stream flows that is relatively untrammeled by modern human control and has retained its primeval / primitive character and influence. What each of the expert reports fails to do is identify the existing human-alterations in the stream channel of Aravaipa Creek that have already modified some elements of the natural hydrograph. These modifications as detailed below are apparently not sufficient to have caused any degradation of the aquatic and terrestrial ecosystem. In addition, the potential annual variability in stream flow, which can change by one or two orders of magnitude from one year to the next and is known to change by over two orders of magnitude at the known peak flow, has no apparent long-term impact on the ecosystem. SWCA will make the case that extracting a small portion of flood flows will be largely undetectable within the natural hydrograph and therefore have no impact on the wilderness resources.

Fish Barrier

In an attempt to reduce the numbers of non-native fishes moving into the upper reaches of Aravaipa Creek, the U.S. Bureau of Reclamation (BOR) in 2001 installed a fish barrier near the USGS gage approximately six miles below the west end of the wilderness boundary. The fish barrier is essentially a small dam with an engineered vertical waterfall in the channel (BOR 2013). This small dam is seen as a necessary structure in an attempt to preclude the movement of non-native fish upstream.

Water Diversions and Pumping

Plateau Resources (2013) has summarized the level of water withdrawals from surface and groundwater both above and below the wilderness area from 1921 to the present. Plateau Resources (2013) has also documented that mining activities in the area of Klondyke, Arizona, during the 1940s and 1950s probably consumed substantial amounts of water that had impacts on stream flow. Plateau Resources (2013) has also indicated that agricultural activities that continue today have the potential to influence the natural hydrograph. Again, these modifications on the hydrograph are apparently insufficient to gain notice in any of the expert reports and must therefore be considered of minor impact if any.

Roads

Approximately 254 miles of roads currently exist within, or enter into, the BLM's Aravaipa Ecosystem Management Plan (BLM 2010). Road 5018 currently crosses Aravaipa Creek at one crossing where the flow can be intermittent and six crossings where the flow is perennial within the planning area. Road 5021 (Turkey Creek Road) crosses the perennial creek approximately 10 times on the drive into the east end of the wilderness (personal observation, Colton Finch). These instream vehicle crossings have some effect on, and have altered the natural hydrograph. Every time a vehicle crosses a wetted stream some in-channel disturbance of habitat occurs. This disturbance can be in the form of increased sedimentation within the water column and/or actual crushing of the in-channel flora and fauna. The maintenance of these roads at stream crossings is known to potentially adversely affect listed species and their habitat (USFWS 2013). Some bank and terrace grading is required for road maintenance after seasonal rains, and larger flood events sometimes require several days of floodplain work utilizing heavy equipment. Typical maintenance after major flood events involves removal of downed trees and limbs and blading floodplain areas where high water destroyed roadways.

An example of the extent to which the stream channel within the creek has been modified for road repairs was a result of a major flood in 1993. At that time, Pinal County used heavy equipment to place a small earthen diversion dam into Aravaipa Creek at a road washout at Mile Post 11.4. The County erroneously believed this work to be covered by an emergency consultation which addressed the temporary low-water crossing. After discussions between the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the USFWS, the dam was removed by the County on December 4, 1993 (USFWS 1995). Road maintenance within the creek is a constant issue for property owners and the agencies responsible for providing access. The road was damaged in two areas during flooding in January and February of 1993 and the flood damage was not a unique situation. According to members of the Aravaipa Property Owners' Association, the road washed out at the same site where the earthen dam was placed in 1967, 1978, 1983, and 1993 (USFWS 1995). These road maintenance and use activities all have the potential to influence the natural hydrograph and flow characteristics of the stream; but again, they are apparently not of sufficient magnitude to concern the hydrological and ecological experts (cited above) in their demands for adhering to the natural hydrograph and claiming all of the water is necessary to fulfill the purpose of the wilderness.

Recreation Impacts

Overuse by day and overnight visitors to the Aravaipa Canyon area has contributed to erosion and degradation of the aquatic and riparian habitats (USFWS 2013). Overuse of the area has required the BLM to focus on campsite proliferation and annually monitoring camping sites and human impact conditions and take remedial actions when resource damage reaches certain undefined levels of impact (see BLM 2010). While these activities may have small effects on the overall condition of the aquatic and riparian habitats, they are ecosystem disturbances (often in floodplain habitats) that require monitoring and management and are hardly representative of a pristine environment.

Aravaipa Creek’s 22-mile-long perennial reach, is an area that supports one of the last remaining assemblages of native desert fishes in Arizona, and is the primary reason agency personnel and conservationists focus on maintaining a “natural hydrograph” within the area. It is also a major tourist attraction. So many visitors want to access the area that the BLM has restricted entry to 50 visitors a day. Most, but not all, of the recreational activities attracting the tourist is hiking; with much of the hiking concentrated in the streambed where benthic habitat is disturbed and sediment concentration of the water column is increased with each footstep. Where hiking is not in the streambed it is in the riparian areas of floodplain banks and terraces. For the period 1992–2012, approximately 82,100 visitors entered the wilderness (147,423 visitor-days) for an average of 7,371 visitor-days per year (Moore 2013). Other activities that have the potential to disrupt the natural ecosystem include camping and picnicking. In 2004 it is estimated that 2,354 vehicles entered Aravaipa Canyon downstream of Bear Canyon and 1,496 vehicles drove into Turkey Creek (USFWS 2013).

In their final Biological Opinion for the BLM’s Aravaipa Ecosystem Management Plan, the USFWS determined that recreational activities including hiking and road use and maintenance in Aravaipa Creek would in fact cause some level of “take” of the endangered loach minnow and spikedace (USFWS 2013). The final Biological Opinion summarized that, as long as the activities in Aravaipa Creek were managed to maintain or improve Critical Habitat and the Primary Constituent Elements (PCEs) for the listed fish species, the activities associated with recreation and road use and maintenance would not be problematic (USFWS 2013). The PCEs and characteristics of Critical Habitat known to protect and nurture the native fishery of Aravaipa Creek are presented in the next section.

Fishes of Aravaipa Creek

Among the resources considered for protection within Aravaipa Canyon Wilderness is the extant native fish community consisting of two endangered species, the loach minnow (*Tiaroga cobitis*) and spikedace (*Meda fulgida*), as well as one candidate for federal listing (roundtail chub, *Gila robusta*) and four unprotected non-game native species (Sonora sucker, *Catostomus insignis*; desert sucker, *Catostomus clarkii*; longfin dace, *Agosia chrysogaster*; and speckled dace, *Rhinichthys osculus*). Federally endangered Gila topminnow (*Poeciliopsis occidentalis*) and desert pupfish (*Cyprinodon macularius*) have also been stocked into southern tributaries of Aravaipa Creek as part of a safe harbor agreement between The Nature Conservancy and the USFWS (2005). Fish monitoring within Aravaipa Canyon began in the 1940s and continues in some form to the present day. Prominent publications based on these data include studies of fish diversity and distribution (Barber and Minckley 1966; Voeltz and Davidson 2002; Stefferud and Reinthal 2005), responses of fish communities to flooding (Meffe and Minckley 1987), feeding interrelations (Schreiber and Minckley 1981), and habitat use of the two listed species (Rinne 1989, 1991). W.L. Minckley (Arizona State University) has a complete database of fish collections through 2000, when surveys were taken over by P.R. Reinthal (University of Arizona). Surveys by the University of Arizona continue to the present.

Minckley and Meffe (1987) posit that natural, catastrophic flooding slows or even precludes establishment of non-native fish species in desert streams such as Aravaipa Canyon, as evidenced by the lack of additional invasions or observations of non-native fish after large floods in some drainages (>1 order of magnitude above mean discharge). The flood of record for Aravaipa Creek occurred in October 1983, with peak flows of roughly 30,000 cfs that were more than 15 feet above modal flows in some canyon sections. The flood mobilized almost all of the substrate and destroyed roughly half of the mature gallery riparian forest (Meffe and Minckley 1987). Despite the catastrophic nature of this flood and subsequent floods, all three non-native species present in the wilderness portion of Aravaipa Creek prior to this flood are still extant and are observed as incidental captures during fish monitoring. Other non-natives, including red shiner (*Cyprinella lutrensis*) and bullhead catfish (*Ameiurus* spp.), are locally abundant in lower Aravaipa Creek, while green sunfish (*Lepomis cyanellus*) are rare but persistent within one tributary and around its confluence with Aravaipa Creek (Reinthal, unpublished data).

Figures 1 and 2 present native and non-native fish abundance and annual stream flow (acre-feet), respectively, during the period of monitoring in Aravaipa Creek beginning in 1965 (fish data from Arizona State University and the University of Arizona monitoring of Aravaipa Creek 1965–2012; hydrological data from Plateau Resources 2013; note during the water years 2003-2005 the USGS gage was inoperable) (Reinthal, unpublished data[8]).

[8] The graphics and associated text represented in Figures 1 and 2 are Confidential Material produced by Dr. Peter Reinthal and are to be only disclosed to the counsel, experts and representatives directly involved in this litigation (In re General Adjudication of All Rights to Use Water in the Gila River System and Source. Civil Nos. W1, W-2, W-3 and W-4 (Consolidated); Contested Case No. W-1-11-3342).

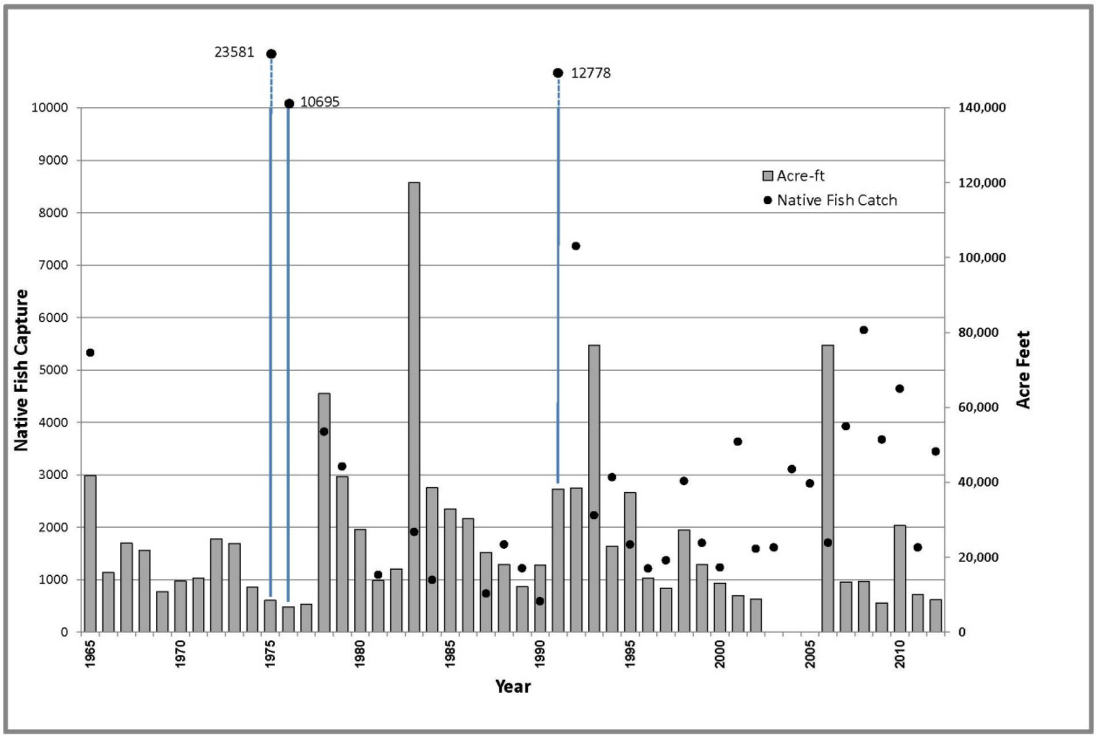


Figure 1. Native fish abundance over time compared to total annual acre-feet flowing through Aravaipa Creek. (Seven species of native fishes are represented.)

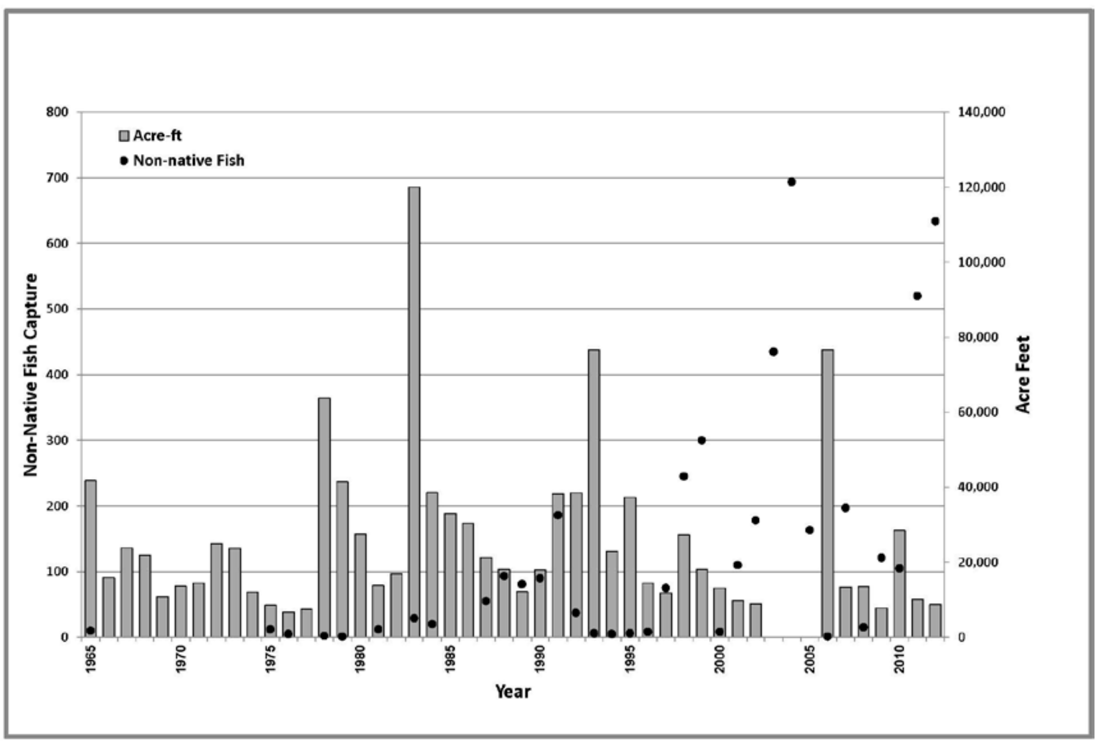


Figure 2. Non-native fish abundance over time compared to total annual acre-feet flowing through Aravaipa Creek. (Ten species of non-native fishes are represented.)

Data were summarized and only those years with a complete sampling of all three Aravaipa Creek reaches (upper, middle, and lower) were used. Figures 1 and 2 present fish data on different scales by an order of magnitude between native and non-natives. Through time, including to the present, the native fish have far outnumbered the non-natives, but it is important to note that the latter are increasing. Native fish species numbers have persisted for decades despite wide variations in stream flow through Aravaipa Creek. The steady increase in numbers of non-native species that compete with and prey upon native fishes is of concern to fishery managers.

Abundance of native species was highly variable, but relatively low during high flow years of the 1980s and 1990s (see Figure 1). Overall numbers of native fishes increased dramatically beginning in the late 1990s through the present with many years above 2,000 individuals captured. As can be seen in the histograms of annual flow volume in the figures, this increase in abundance corresponded with a decade of some of the lowest flow years on record. Non-native fish abundance over time was quite low through about 1995 (see Figure 2). Beginning with the low water years that coincide with drought conditions throughout the arid southwest, non-native numbers have increased dramatically, but the causative factors for this increase are unknown.

Although current population abundance trends of native fishes within Aravaipa Canyon Wilderness continue to outnumber the non-natives, the long-term persistence of the fish fauna of the area is still tenuous due to the possibility of illegal introductions of new non-native species, or the further spread of five extant non-native species.

While natural flows (including floods) are important structuring mechanisms (Poff et al. 1997) and flash floods may reduce the abundance of non-native fish (Minckley and Meffe 1987), floods are probably not the primary mechanism preventing establishment of additional non-native species in Aravaipa Creek, nor are floods the primary reason Aravaipa Creek has avoided the proliferation of non-native species seen in other desert streams throughout the southwest (Minckley and Deacon 1968; Minckley and Marsh 2009). Little is known about the distribution, trends, or abundance of red shiner and bullhead catfish due to logistical constraints of sampling within the wilderness and sampling activities targeting native fish species. No additional non-native species have been observed in the naturally flowing Aravaipa Creek. However, the observed reduction in additional invasions of non-native fish reported by Minckley and Meffe (1987) was not independent of concurrent changes in hydrology and connectivity of Aravaipa Creek. The two most likely mechanisms precluding further invasion of non-native species in Aravaipa Canyon are the intermittent flow and corresponding depauperate fish community of the San Pedro River, the most likely source of new immigrants, and the placement of a large, federally funded fish barrier placed in Aravaipa Creek near the USGS gage approximately 6 miles below the west boundary of the wilderness (BOR 2013).

Despite the fish barrier, the regular incidence of catastrophic floods, and restricted sources of re-invasions, non-native species within Aravaipa Canyon continue to persist. Minckley and Meffe (1987) determined that flows in canyon-bound streams needed to approach one order of magnitude above the mean stream flow to affect non-native fish abundance. They also stated that floods of two orders of magnitude above the mean stream flow were required to shift the fish community in favor of native fishes. Minckley and Meffe's assertion that high magnitude floods can benefit native fishes applies primarily to canyon-bound reaches of streams where a developed floodplain is limited. In streams that are not limited by canyon walls, the potential impact of high magnitude floods is attenuated across the floodplain habitats that allow fishes to escape the high velocity flood currents. In Aravaipa Creek one order of magnitude above mean monthly flow of about 30 cfs (see Swanson 2013 and JE Fuller et al. 2000 for range of flows through time) would be about 300 cfs, two orders of magnitude would be nearly 3,000 cfs. Floods of this magnitude occur with some regularity. For example, at the east end of the wilderness, Plateau Resources (2013) found that instantaneous flows of 2,890 cfs, 9,220, cfs, 14,200 cfs, 18,800 cfs, and 24,300 cfs return on a period of 2, 10, 25, 50, and 100 years, respectively (Plateau Resources 2013).

There are other examples of streams in the Southwest that have a natural hydrograph and the associated seasonal flood events, yet their native fish community is severely altered or impaired or non-existent. Systems like the upper Verde River and its tributaries are impaired by the presence of non-native species (Arizona Game and Fish Department 2005; Rinne 2012). Rinne (2012) found that large Verde River floods reduced both native and non-native numbers in the short term, but abundances rebounded to pre-flood levels quickly. In the short term, Verde River native fishes benefit by the temporary reduction in non-native numbers, but short-lived species like spikedace can become extirpated within the intervals between flood events of the magnitude required to reduce non-native numbers. In the upper Gila River and its tributaries in New Mexico studies found a similar situation to the upper Verde River. These examples show the natural hydrograph was in itself unlikely to suppress non-native fishes sufficiently to benefit native fish species (Rinne 2012; Propst et al. 2008). Recent findings by fishery researchers working on both these rivers concluded that in order for native fish communities to persist, active management to suppress non-native fish populations would be required (Gido et al. 2013).

It is clear that maintenance of a natural hydrograph alone is not the primary management need for native fishes. Propst et al. (2008) assert that although the natural flow regime is beneficial to native fish fauna, floods alone will be insufficient to ensure persistence of imperiled native fish fauna. Minckley and Marsh (2009) characterize the situation more clearly:

> *In the final analysis, there probably are no aquatic habitats left that are unaffected in some way by the presence or actions of modern humans. Physical and chemical impacts can, but do not necessarily, spell the demise of native fishes. In fact, our observations as well as those of others are that many native kinds, absent conditions of temperature, oxygen, or toxic substances that are so extreme as to be lethal, will do just fine as long as there is water, even in the most altered places. The same cannot be said of the biological pollution manifested by the introduction and establishment of non-native species. Across the arid Southwest, and with few exceptions, natives have declined or disappeared where non-natives are found. Non-natives are indicted as the most significant factor in the endangerment of the regional fauna, and as the primary obstacle to the recovery of native species.* (p. 50)

Primary Constituent Elements and Critical Habitat

The determination of PCEs for loach minnow and spikedace is an important component of species recovery. PCEs are published by the USFWS for each species during the listing and critical habitat designation process. For the endangered spikedace and loach minnow, PCEs are summarized in Table 1 (modified from 50 CFR Part 17 10810, Endangered Status and Designation of Critical Habitat). It is important to recognize that the USFWS, the ultimate enforcer of the Endangered Species Act, considers PCEs to include those habitat features required for the physiological, behavioral and ecological needs of the species. Most importantly, and critical to our analysis of how much water do the fish need, is the fact that the PCEs describe appropriate flow regime, velocities, and depths, microhabitats, temperature needs, acceptable pollutant levels, and allowed abundances of non-native competitors and predators when they are known.

Table 1. Primary Constituent Elements for Loach Minnow and Spikedace

Primary Constituent Element	**Description**
Flows	Perennial, or interrupted stream courses that are periodically dewatered but serve as connective corridors between occupied or seasonally occupied habitats
Depth	Generally less than 3.3 feet (1 meter)
Velocities	Slow to swift, between 1.9 and 31.5 inches per second(5–80 centimeters/second)
Stream Microhabitats	Glides, runs, riffles, margins of pools and eddies
Substrate	Sand, gravel, and cobble, with low or moderate amounts of fine sediment and substrate embeddedness
Gradient	Less than approximately 1.0 percent
Elevation	Below 6,890 feet (2,100 meters)
Water Temperatures	Between 46.4 to 82.4 degrees Fahrenheit; 8.0 to 28.0 Celsius
Pollutants	None or low levels present
Non-native Aquatic Species	None, or present at levels sufficiently low as to allow persistence of native species
Flow Regime	Natural and unregulated, *or if modified or regulated, regimes that allow for adequate river functions, such as flows capable of transporting sediments* [our emphasis].

The PCE for flow regimes in designated critical habitats for spikedace and loach minnow covers a broad spectrum of riverine conditions and includes the natural variation in flows between years and across the full suite of dry and wet years. Flows that provide for "adequate" river functions and sediment transport for habitat building meet this criterion. This flow threshold for river function is not an absolute number but rather a range of flows that usually includes daily and seasonal variability.

Critical habitat was designated for the loach minnow and spikedace in 2012 (see 77 FR 10810). In the critical habitat designation (77 FR 10854) the USFWS lists five actions that may destroy or adversely modify critical habitat:

1. Actions that would significantly diminish flows within the active stream channel.
2. Actions that would significantly alter the water chemistry of the active channel.
3. Actions that would significantly increase sediment depositions within a stream channel.
4. Actions that could result in the introduction, spread, or augmentation of aquatic species in occupied stream segments, or in stream segments that are hydrologically connected to occupied stream segments, even if those segments are occasionally intermittent, or introduction of other species that compete with or prey on spikedace or loach minnow.
5. Actions that would significantly alter channel morphology.

The USFWS summarizes that, "*Critical habitat that is managed to maintain or improve the PCEs for loach minnow or spikedace over time will maintain or improve these characteristics*" (USFWS 2013, p. 24).

Thus, the question is: "Can some portion of the natural hydrograph be harvested to collect water that does not remain in the system and not compromise PCEs or critical habitat values?" SWCA believes the answer is "yes," and we explore this potential below.

Harvesting Flood Flows

All the available data on the Aravaipa Wilderness Area indicate that ground water supplies, those resources that inevitably feed the base flow of the stream, are stable "*and in or very nearly in a steady state condition where annual recharge and discharge are balanced over time*" (Swanson 2013, p. 2; see also JE Fuller et al. 2000). Stable groundwater supplies are directly related to the health of the riparian community, and other than some minor impacts by recreationists (USWS 2013), there are no data indicating anthropogenic threats to the vigor of that vegetation currently exist. Indeed, the water use by humans in the area today is significantly reduced from that of several decades ago and is not likely to increase anytime in the near future (pers. comm. Rich Burtell, Plateau Resources, to Steve Carothers October 2013). It has also been documented that at least 15,156 af in unconstrained flood flows pass the USGS gage below Aravaipa Canyon in an average year and do not stay within the system (see Swanson 2013). Based on our understanding of riparian and aquatic ecosystem dynamics, it is our opinion that not all of the water in floods of this magnitude is necessary to maintain ecosystem functions within Aravaipa Canyon, and thus all the water is not necessary to fulfill the requirements of the wilderness area's ecosystem. Consequently, some portion of such flood flows can be conservatively harvested for other uses.

After reviewing the literature on stream flow characteristics within desert ecosystems, including the above referenced expert reports (including their citations), the USFWS summaries of PCEs and critical habitat needs for the listed fishes, and calling upon our combined 100-plus years of experience in studying fish communities and riparian habitats throughout the Southwest, we provide below an evaluation that the federal claim for Aravaipa Creek is overstated. A model that analyzes two time periods of flow data on Aravaipa Creek has been developed to arrive at the alternative (52 years from 1932 to 1984 and 81 years from 1932 to 2012). The stream flow data upon which the model is based were recorded approximately 6 miles west of the wilderness boundary at the only USGS gaging station on the stream. The OEM is designed to primarily harvest flood flows in such a manner as to maintain all the designated elements of critical habitat, to maintain or improve PCEs, and to maintain all the critical elements of the natural hydrograph.

The OEM is based on carefully maintaining the following five characteristics of the natural flow regime described by Poff et al. (1997). It is well known that these characteristics are important to native fish life histories, abundance and diversity of the food web, and maintenance of physical habitat and connectivity:

1. Magnitude: The largest flood on record (estimated return interval of about 100 years) occurred in October 1983 with an estimated maximum instantaneous discharge of 30,000 cfs (Plateau Resources 2013). This maximum flood was over two orders of magnitude above the normal base flows of Aravaipa Creek. There is nothing in our extraction model that would in any way interrupt this kind of maximum flood.
2. Frequency: Floods greater than 100 cfs (~8 inches above base flow at the USGS gage) during the relatively active 2013 summer monsoon season occurred on average every 9.2 days. Floods during the wet winter of 2010–2011 occurred on average every 32 days and lasted 4 days on average. These flood flow frequencies are clearly of a stochastic nature, controlled completely by climatic events. Implementation of the OEM will not in any way influence this frequency.
3. Duration: The largest flood on record (October 1983) maintained elevated flows for over 9 days, and with additional storms may have contributed to slightly elevated base flows for as long as 6 months (USGS gage data). Winter storms are typically much larger precipitation events, and the lower evaporation and evapotranspiration rates result in longer duration floods. Summer flood events, on the other hand, are short in duration. The largest flood of the past 5 years peaked at over two orders of magnitude greater than base flow and then returned to base flow within

14 hours (USGS gage data). This is a very rapid recession rate, indicating that the slope of the curve of the descending hydrograph is normally very steep, a situation not uncommon in canyon bound systems. JE Fuller et al. (2000) found that flood duration rates in Aravaipa Creek were much more abbreviated in summer (average of 2.1 days) than in winter (5.5 days) (pp. 3–26). The OEM is designed to collect more of the flood waters on the naturally steep descending slope of the summer monsoon floods.

4. Timing: The Aravaipa Creek drainage experiences two pronounced wet periods: one during the summer "North American Monsoon" season of July–September, and another during winter when frontal storms come in from the Pacific Ocean. Flood events within these two time periods are unpredictable and, as has been stated previously, have substantial variation between one year and the next.
5. Rate of change: As has been described, Aravaipa Canyon experiences rapid increases in discharges due to "flash floods." The largest flood of the last 5 years occurred on 24–25 July 2006. A flash flood raised discharges from 31 cfs to 4,020 cfs in less than 15 minutes. Roughly 12 hours after peak discharge, the slope of the descending limb of the hydrograph was shallower, but flows still returned to base flows. The OEM is designed to take advantage of the excess water that is not retained in the system during these high flow events.

As stated earlier, SWCA agrees with the expert reports of Swanson (2013), Bonar and Mercado-Silva (no date), and Lowclouds (2013) that maintaining those critical elements of the natural hydrograph that foster stream channel maintenance and the protection of its riparian habitat, fishery, and wildlife are important and necessary. We also agree with the USFWS that maintaining the PCEs for the listed fishes is important and necessary. However, as we demonstrate below, there is no evidence that maintaining an Aravaipa Creek hydrograph that requires all of the water all of the time is necessary to provide for the environmental parameters necessary to support the aquatic and terrestrial ecosystems in a "natural" condition.

SWCA proposes that water extraction can be scheduled and managed in such a way as to allow the maintenance of the natural flow regime within the bounds of natural variability. In concordance with the current limitation of new non-native fish invasions and riparian habitat protection, some level of water harvesting or extraction will not have a negative effect on the abundance, diversity, and trends of extant native fish species in Aravaipa Creek or in any way negatively impact the riparian community.

Opportune Extraction Model (OEM): Model Construction

SWCA has developed a water extraction model based on historical data that we believe meets ecological and hydrological demands for protection of the wilderness area. The model only extracts water after the ecosystem needs are met. The model only allows for the extraction of water that is surplus to and passes through the wilderness system. The following text fully explains the construction and scientific basis upon which this model is based.

1. The model defines a minimum flow for ecological purposes that must be maintained, with likely values of at least three times the minimum instantaneous discharge in a given year. SWCA has conservatively designated minimum flows between 15–20 cfs. This is based on the fact that actual flows are known to occur for months at 5 cfs or below (JE Fuller et al. 2000; Plateau Resources 2013).We believe this to be a very conservative estimate, as low median flows (15 cfs from 1932 to 2012) have also been known to occur with regularity (Plateau Resources 2013). Fish communities are sensitive to natural perturbations such as extreme low flows, and artificially increasing the frequency of these events could have detrimental impacts on at least two federally

listed fish species. Although natural minimum flows frequently fall well below our defined minimum range, our model does not exacerbate these natural events in frequency or magnitude by additional withdrawal.

2. Maximum instantaneous discharge is an important driver of channel form and location, bed material mobilization, floodplain inundation, and food web structure. The OEM does not allow extraction on the ascending limb of a flood unless it is above a critical, destructive discharge. Minckley (1981 cited in JE Fuller et al. 2000) considered flows above 100 cfs as "destructive flooding." However, JE Fuller et al. (2000) considered destructive flooding (significant changes in bed form, locations of riffles and rapids, loss of overbank vegetation) to occur when daily discharges were greater than 800 cfs. In the interest of conservatism, for the model scenarios run, the OEM only allows extraction at flows above 1,000–3,500 cfs. It is obvious that the term "destructive flood" depends upon value judgments and not a particular science. Thus, for this parameter in our model we have picked a range of flood flows that can clearly be shown to be destructive to the ecosystem's riparian vegetation.

3. The rate of flood recession can be an important variable in the establishment of riparian vegetation (Stromberg 2001, Stromberg et al. 2007); and, it is well known that significant variability exists in the flow recession timescale at a given flow rate depending on climatic and geomorphic variables (Krakauer and Temimi 2011). Thus, in the OEM, the slope of the descending limb of a specific flood's hydrograph is meticulously guarded. For example, the model allows withdrawal only when, for the two preceding days: 1) flows are on the descending limb of a flood, or 2) discharges are level (base flow). This can be modified by some extraction as long as the slope of the recession is within the range of the variability of natural floods in Aravaipa Creek (flows above base line of 15–20 cfs to 30,000 cfs flood of record). Aravaipa Creek is not a snowmelt-driven system where reliable, sustained high flows are necessary for successful reproduction. Some winters get no elevated base flows, yet riparian vegetation flourishes over the short and long term, and native fish still reproduce successfully year after year. This model parameter is also based on the assumption that fish and the riparian vegetation will not respond negatively if a winter flood hydrograph more closely resembles (i.e., is steeper on the recession curve) that of a summer flood hydrograph. This is due to the fact that the fish and riparian vegetation do not rely on consistent winter flooding for recruitment. In fact, there is successful recruitment even when there are no winter floods.

4. An important aspect of extracting water during a flood flow is limited by the system infrastructure that provides for the actual water collection. These systems can be either in stream or off channel. SWCA is not suggesting that a water extraction system be constructed on Aravaipa Creek; we only use this example by analogy to suggest that the possibility exists. SWCA has put a model restriction of 350 to 500 cfs on the infrastructure design. However, during some flood flows sufficient water is available that could be extracted in excess of 1000 cfs without causing a significant change in the pattern of the natural hydrograph.

5. The model attenuates flow to prevent unnaturally rapid changes in discharges as is known to cause ecological disruption in some regulated rivers (see Carothers and Brown 1991). For example, the model permits water extraction only to a level that does not result in recession rates in excess of the long-term pattern of flow within Aravaipa Creek. As an example, if discharge on the descending limb of a flood is 380 cfs, and the infrastructure limit allows extraction of 350 cfs the model does not allow a full amount of extraction to prevent the full discharge from instantly dropping by an order of magnitude. Thus, an attenuating limit of the model is that above a certain discharge (two times the 350 cfs infrastructure limit, for instance),withdrawal is allowed up to the infrastructure limit, but below that discharge, the model prevents extracting more than 50 percent of the flood flow.

Opportune Extraction Model (OEM): Potential Extraction

Examples of how the OEM calculates the amount of water that can be extracted in any given year are illustrated in Tables 2 and 3. Specific details on the limits and parameters of the model calculations for each column in the tables are presented in the box to the right. To illustrate how the model works, SWCA analyzed storm flows reflecting the Aravaipa Canyon hydrograph both before after the date the wilderness area was designated 28 August 1984.

Table 2 portrays a three-week period in late December 1967 and early January 1968, which represents a relatively small, but typical winter storm. Table 3 portrays a three-week period in July and early August of 2006, previously mentioned as a period of destructive flooding that removed approximately 11 miles of riparian habitat. The purpose of the tables is to demonstrate the amount of excess water that could be extracted on the descending and ascending slope of a flood's hydrograph.

For the winter storm, it can be seen in Table 2 that on 15 December the flow was 48 cfs, slightly higher at 53 cfs on 16 December, 86 cfs on 17 December and 78 cfs on 18 December. Since the water flows were below the destructive flow level of 1,000 cfs, the model did not allow any extraction (Column 10). Then on 19 December, the water came up with a destructive flood of 1,730 cfs that went even higher on 20 December to 2,700 cfs, but then quickly dropped to 305 cfs on 21 December. Note on this run, for illustrative purposes, we allowed the model to extract water on the ascending portion of the destructive flood (defined for this run at 1,000 cfs). In the subsequent model runs portrayed below, the model does not allow extraction on the ascending hydrograph. Thus, on 19 and 20 December the model allowed 992 af to be collected each day (Column 10). As the descending hydrograph continued to decline from 21 December to 5 January, the model allows small amounts of water to be extracted (approximately half the flow) up until 4 January, when the base flow control of 20 cfs is reached. The hydrograph depicting the before and after extraction of water during this three-week period is presented in Figure 3. The total amount of water the model would have allowed to be extracted during this three-week period was 2,824 af.

OEM Calculation Parameters in Table 2

Column 1. *Date*: the date prior to and during when the flood starts.

Column 2. *Q-Natural*: the mean daily discharge in cfs. (Q is the hydrological abbreviation for flow.)

Column 3. *Natural Volume*: the total volume of that day's mean daily discharge, in acre-feet.

Column 4. *Q-Post-withdrawal*: the mean daily discharge in cfs after the modeled amount of water has been extracted.

Column 5. *Descending or Level*: a model decision-influencing column. If the "Descending Trigger" is turned "on" ("Model Parameters"), then this column is active. On the other hand, if the Descending Trigger is turned "off", then it does not matter which part of the hydrograph you are observing. In the OEM, this column will always say yes, because the modeler is not concerned about where on the hydrograph they are extracting. If this column is active, then this column says withdrawal is possible when, for the two preceding days, 1) flows are on the descending limb of a flood, or 2) discharges are level (base flow).

Column 6. *Destructive* (or non-destructive flow): a model decision-influencing column. If discharges are above the user-defined "Destructive Q" discharge (either 1,000 or 3,500 depending upon the model run), then the model extracts water whether the flood is ascending or descending. This column will likely be rarely if ever used (large floods are rare), but does allow for increased water extraction during very high flows.

Column 7. *At Least Minimum Flow*: a model decision-influencing column. If discharges (Column 2) are above the user-defined minimum flow (15–20 cfs), then this criterion is satisfied and the model allows extraction.

Column 8. *Extraction*: the model apex column that produces a "yes" or "no" decision for water extraction. Thus, if conditions described in Columns 5, 6, and 7 are satisfied, then the model allows extraction of water on that day.

Column 9. *CFS Extracted*. assesses how much water in cfs the model withdraws (assuming Column 8 is "yes") on that day.

Column 10. *Acre-Feet Extracted*: assesses how much water in acre-feet the model withdraws on that day.

Table 2. Model water extraction example over a three-week period in late December 1967 and early January 1968. This is a typical winter storm.

1 Date	2 Q-Natural	3 Natural Volume	4 Q-Post-Withdrawal	5 Descending or Level	6 Destructive	7 At Least Minimum Flow	8 Extraction	9 CFS Extracted	10 Acre-feet Extracted
12/15/1967	48	95	48	no	no	yes	no	0	0
12/16/1967	53	105	53	no	no	yes	no	0	0
12/17/1967	86	171	86	no	no	yes	no	0	0
12/18/1967	78	155	78	no	no	yes	no	0	0
12/19/1967	1,730	3,431	1,230	no	yes	yes	yes	500	992
12/20/1967	2,700	5,355	2,200	no	yes	yes	yes	500	992
12/21/1967	305	605	305	no	no	yes	no	0	0
12/22/1967	250	496	135	yes	no	yes	yes	115	228
12/23/1967	199	395	110	yes	no	yes	yes	90	178
12/24/1967	148	294	84	yes	no	yes	yes	64	127
12/25/1967	130	258	75	yes	no	yes	yes	55	109
12/26/1967	87	173	54	yes	no	yes	yes	34	66
12/27/1967	65	129	43	yes	no	yes	yes	23	45
12/28/1967	63	125	42	yes	no	yes	yes	22	43
12/29/1967	53	105	37	yes	no	yes	yes	17	33
12/30/1967	55	109	55	no	no	yes	no	0	0
12/31/1967	67	133	67	no	no	yes	no	0	0
1/1/1968	45	89	45	no	no	yes	no	0	0
1/2/1968	29	58	25	yes	no	yes	yes	5	9
1/3/1968	22	44	21	yes	no	yes	yes	1	2
1/4/1968	20	40	20	yes	no	no	no	0	0
1/5/1968	19	38	19	yes	no	no	no	0	0

Table 3 presents the model water extraction for the July–August 2006 destructive flood. Beginning sometime between 27 and 28 July, the creek base flow increased from 6.9 cfs to a flood flow of 386 cfs, which then increased by 29 July to a major flood of 8,180 cfs. However, it was not until 29 July, the date at which base flows began to increase, when the model parameters and limits began to allow for the extraction of some water. On 29, 30, and 31 July and again on 1 August the model allowed 694 af to be collected for each day. Note that on 31 July the flow was below the model parameter of a destructive flood (3,500 cfs for this model run), but it is still well above the minimum flow *and* the flows have been descending for 2 days. Thus, the model continues to extract water. On 1 August, the discharges come back up (from 3,150 cfs to 12,700 cfs), so normally the model would not allow extraction; however, the flow is above the destructive discharge so the model extracts. On 2 August, the flow is below the destructive discharge but it is only one day after the flood (when gravel and seeds and organic debris are likely still entrained), so the model does not extract until the second day after that flood, which is 3 August. By then the flows have fallen below the attenuation trigger, so the model only allows extraction as a proportion (50 percent) of what is above the minimum discharge restriction of 20 cfs. The total amount of water the model would have allowed to be extracted over the 10-day period between 29 July and 2 August is 3,053 af.

Table 3. Model water extraction example over a three-week period in late July and early August, 2006. This is a typical monsoon.

1 Date	2 Q-Natural	3 Natural Volume	4 Q-Post-Withdrawal	5 Descending or Level	6 Destructive	7 At Least Minimum Flow	8 Extraction	9 CFS Extracted	10 Acre-feet Extracted
7/25/2006	3	7	3	no	no	no	no	0	0
7/26/2006	4	8	4	no	no	no	no	0	0
7/27/2006	7	14	7	no	no	no	no	0	0
7/28/2006	386	766	386	no	no	yes	no	0	0
7/29/2006	8180	16225	7830	no	yes	yes	yes	350	694
7/30/2006	6370	12635	6020	no	yes	yes	yes	350	694
7/31/2006	3150	6248	2800	yes	no	yes	yes	350	694
8/1/2006	12700	25190	12350	no	yes	yes	yes	350	694
8/2/2006	2270	4503	2270	no	no	yes	no	0	0
8/3/2006	160	317	90	yes	no	yes	yes	70	139
8/4/2006	127	252	74	yes	no	yes	yes	54	106
8/5/2006	188	373	188	no	no	yes	no	0	0
8/6/2006	68	135	68	no	no	yes	no	0	0
8/7/2006	52	103	36	yes	no	yes	yes	16	32
8/8/2006	75	149	75	no	no	yes	no	0	0
8/9/2006	42	83	42	no	no	yes	no	0	0
8/10/2006	137	272	137	no	no	yes	no	0	0
8/11/2006	94	186	94	no	no	yes	no	0	0
8/12/2006	113	224	113	no	no	yes	no	0	0
8/13/2006	38	75	38	no	no	yes	no	0	0
8/14/2006	19	38	19	yes	no	no	no	0	0
8/15/2006	88	175	88	no	no	yes	no	0	0

Figure 3 is a graphic representation of the hydrograph described in Table 3 without extraction (blue line) and with extraction (red line). As is clear from this figure, the pattern of the natural hydrograph is preserved even with the extraction of over 3,000 af of flood water. Figure 4 represents another sample model run of a winter flood pattern for a three-month period in 2010 during which the model would have allowed the extraction of approximately 1,267 af.

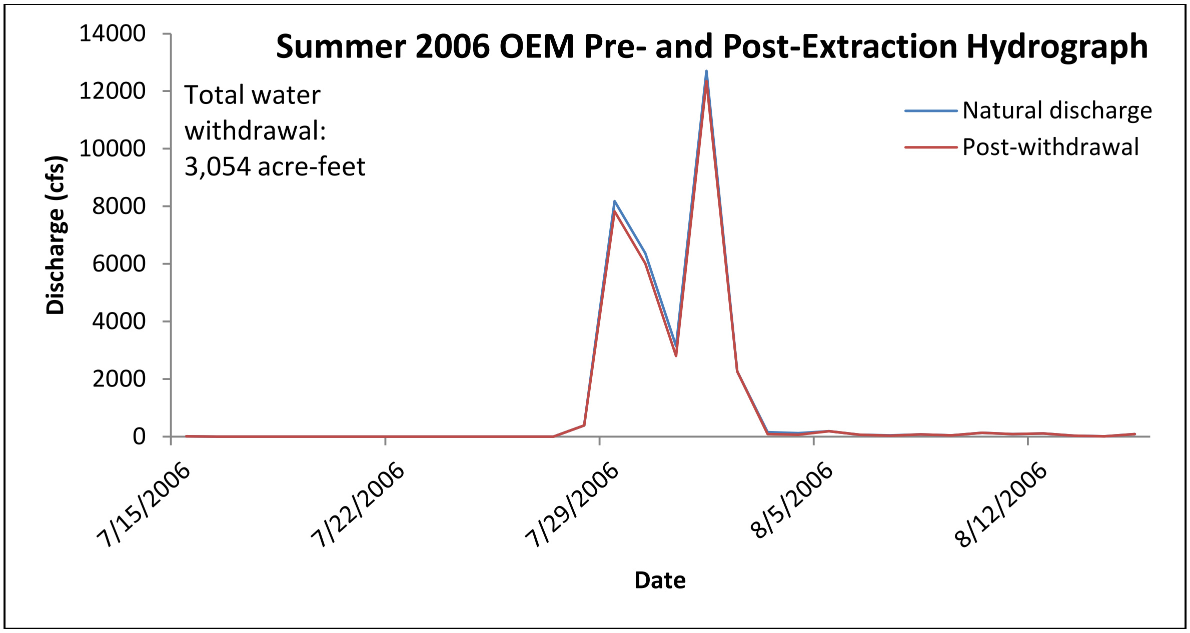


Figure 3. Discharge of Aravaipa Creek based on modeled extraction scenario during a large monsoon flash flood (see Table 3). The blue line is the natural discharge, and the red line represents what the discharge would be after extraction. This flood sequence yielded over 3,000 acre-feet of water in the first week.

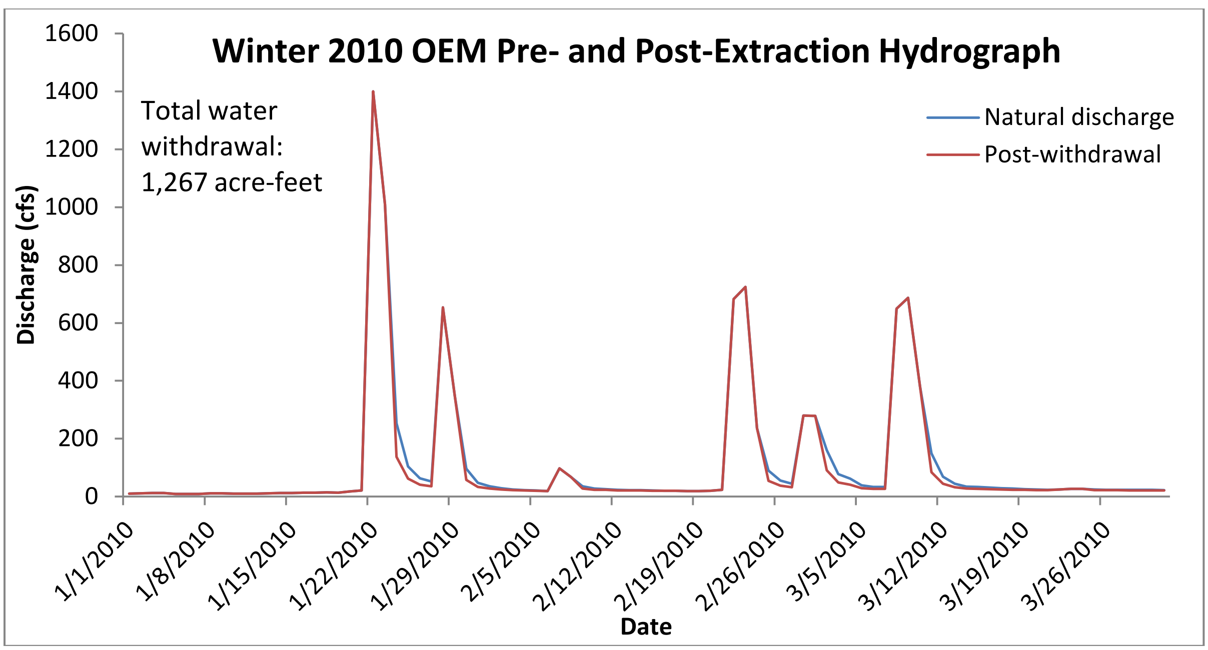


Figure 4. Discharge of Aravaipa Creek based on modeled extraction scenario during a typical winter flood sequence. The blue line is the natural discharge, and the red line represents what the discharge would be after extraction. This scenario yielded over 1,267 acre-feet of water in three months.

For additional examples of how the OEM calculates water extraction we also analyzed the Aravaipa Canyon hydrograph over the full 81years of available flow data. Again, we calculated the amount of excess flood water that can be made available for extraction without compromising the ecological needs of the riparian habitat and aquatic resources for two model scenarios. The two model scenarios differed in three ways: Scenario 1 allowed the maximum withdrawal to be limited to 350 cfs, the destructive flood to be defined at 3,500 cfs, and the minimum flow defined at 20 cfs. Scenario 2 changed these extraction parameters to 500 cfs for the maximum withdrawal, 1,000 cfs to define the destructive floods, and 15 cfs to describe the minimum flow. The results of these scenarios are presented in Figure 5. Scenario 1 and Scenario 2 allow for an average annual extraction of 1,148 af and 1,988 af, respectively. The long-term extraction over the period of record between Scenario 1 and Scenario 2 is 76,516 af and 142,005 af, respectively. Just calculating the difference for the past 20 years (1993 to 2012), the amount of water generated by Scenario 1 (22,960 af) and Scenario 2 (39,761 af) differed by almost 50 percent.

SWCA believes that Scenario 2, while extracting almost twice as much water as Scenario 1, or an average of 1,988 af compared to 1,148 af, is an appropriate level of extraction. The graphical representations of each of these scenarios' impacts on the natural hydrograph show a relatively small difference. Indeed, the pre- and post-hydrographs for Scenario 1 are almost indistinguishable, while Scenario 2 collects substantially more of the destructive peak of the January 2010 flood.

It is our opinion that the OEM is extremely conservative and other model approaches are likely to indicate that more of the excess flood water could be available. The study on the San Pedro River by Jackson et al. (1987) indicated that only 60 percent of the flood waters were necessary for river ecosystem maintenance, and it is likely additional study will support their findings.

Conclusions and Recommendations

After reviewing the available data on the historic flow characteristics of Aravaipa Creek and the known biological needs of the ecosystem elements within the Aravaipa Canyon Wilderness Area dependent upon that stream flow, SWCA concludes that the general pattern of the natural hydrograph is important to the maintenance of the riparian and aquatic ecosystem. This general pattern of the natural hydrograph includes periods of very low flow, periods of relative stability in stream flow (base flow) and periods of winter and summer flood flows. It is also clear from the literature that the riparian ecosystem and endangered fishery of Aravaipa Canyon is healthy and functioning, and current and apparently minor threats to the riparian habitat result from recreation and natural destructive flood flows. It is also apparent that because of the constant re-invasion of non-native fishes, maintenance of a natural hydrograph alone is not the primary management need for native fishes.

Of the four expert reports provided by the Department of Justice, in their attempt to establish the amount of water required to maintain the resources of the wilderness area, SWCA agrees with the authors as to the importance of maintaining the natural pattern of the annual hydrograph. However, we disagree with their opinions that *all* of the water passing through the area is essential to the maintenance of those stream resources. SWCA believes that each of the DOJ experts simply errs on the side of caution and decrees that all of the water is essential, in lieu of empirically demonstrating how much water is necessary for any specific ecosystem or wilderness function. The DOJ experts all also rely on value judgments and not scientific facts to come to their conclusions on wilderness water needs.

The experts make no attempt to indicate why "any" derived departure from the natural physical, chemical, and biological conditions in an aquatic ecosystem (no matter of what magnitude or of what nature human) will have short- and long–term consequences to the native biota; they simply make unsupported statements to attempt to make the case that all the water is required for wilderness maintenance.

SWCA concludes that on average a significant amount of flood water passes through the wilderness system, is not retained there to serve in a biological function, and represents a portion of the annual volume of water that could be made available for purposes incidental to the maintenance of the wilderness.

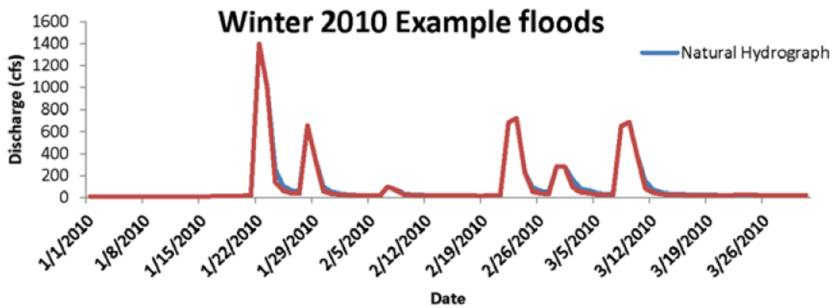
With the development of the OEM, SWCA has made the effort to empirically demonstrate how much of the un-impounded flood flows are *not* necessary to the protection of the natural hydrograph and are therefore available for other beneficial uses. Model results indicate that depending upon small changes in the controls dictating the pattern of water extraction (infrastructure ability to collect flood water, minimum flow retention, definition of destructive floods, etc.) from 1932 to 1983, almost 10 percent (over 1,200 af) of the average annual volume of un-impounded flood flow (15,156 af) is available for extraction without compromising the riparian and aquatic ecosystem.

It is our opinion that the OEM is extremely conservative and other model approaches are likely to indicate that more of the excess flood water could be available. The study on the San Pedro River by Jackson et al. (1987) indicated that only 60 percent of the flood waters were necessary for river ecosystem maintenance and it is likely additional study will support their findings.
We reserve the right to evaluate additional evidence or scientific resources, including any expert reports submitted by any other party, and to revise these opinions accordingly.

SCENARIO 1

Extraction stipulations	
Max withdrawal:	350
Destructive Q:	3500
Minimum flow:	20
Descending trigger:	on
Attenuator:	on
Attenuating trigger:	700
Proportion withdrawn:	0.5

Results
Total withdrawal sum:
76516.48775
20-yr withdrawal sum:
22960.996
20-yr mean withdrawal:
1148.0498



SCENARIO 2

Extraction stipulations	
Max withdrawal:	500
Destructive Q:	1000
Minimum flow:	15
Descending trigger:	on
Attenuator:	on
Attenuating trigger:	700
Proportion withdrawn:	0.5

Results
Total withdrawal sum:
142005.7072
20-yr withdrawal sum:
39761.241
20-yr mean withdrawal:
1988.06205

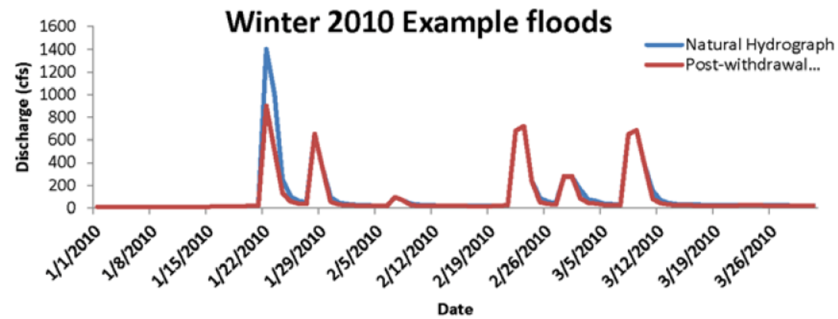


Figure 5. The water extraction results of two model runs. The differences in the model runs include extraction limitations in maximum withdrawal (350 cfs or 500 cfs), the definition of a destructive flood (1,000 cfs or 3,500 cfs), and the minimum flow (15 or 20 cfs) triggers. Scenario 2 allows for the harvesting of almost 2,000 af of water per year over the 20-year period 1993–2012.

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